Naval Environmental Prediction Research Facility
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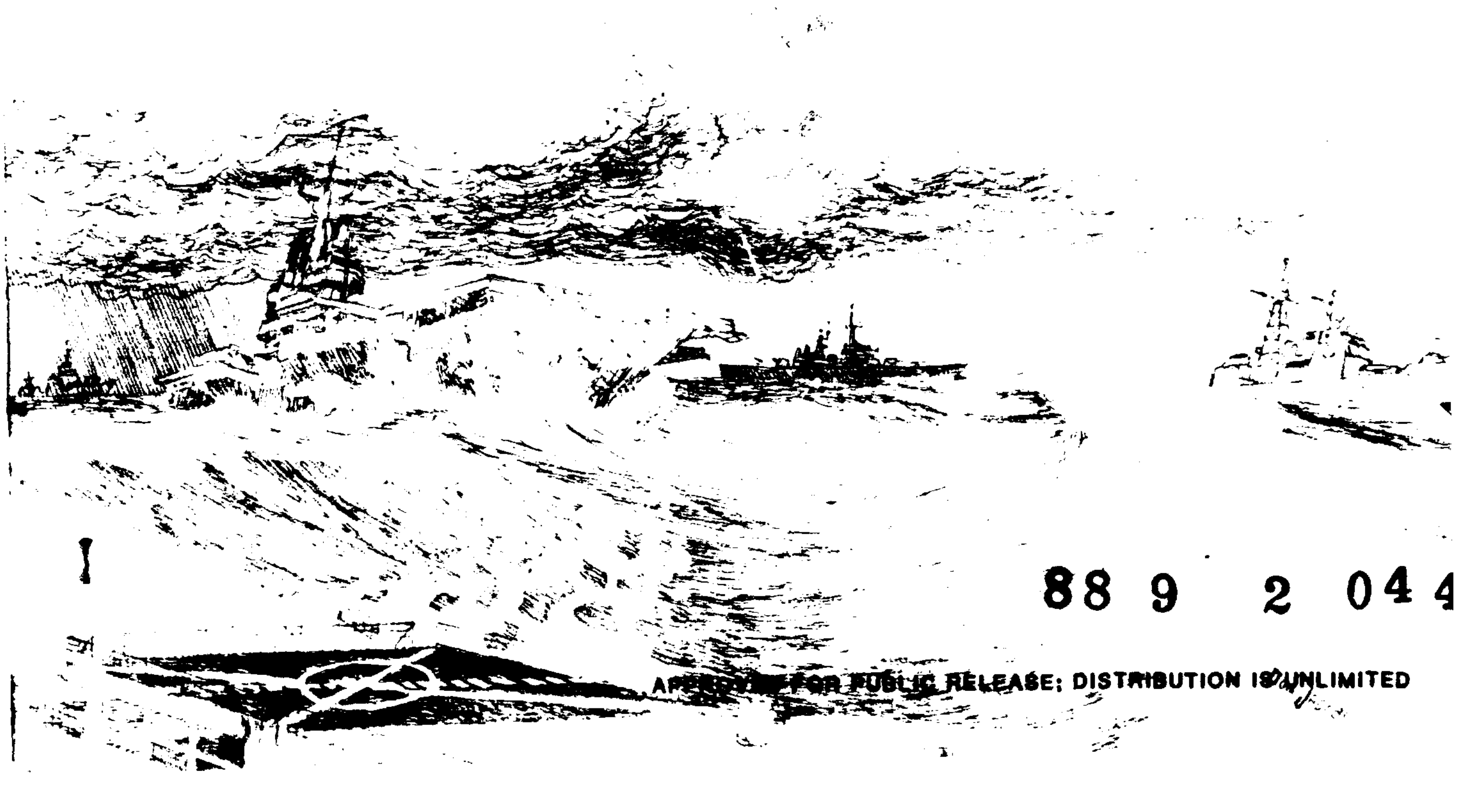
SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

18. IBIZA



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This handbook for the port of Ibiza, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

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CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (COMNAVOCEANCOM) requirements validated by the Chief of Naval Operations (OP-096).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to Naval Oceanography Command Center (NAVOCEANCOMCEN), Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

W. L. SHUTT
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
16	BARCELONA, SPAIN
17	PALMA, SPAIN
18	IBIZA, SPAIN
19	POLLENSA BAY, SPAIN
20	LIVORNO, ITALY
21	LA SPEZIA, ITALY
22	VENICE, ITALY
23	TRIESTE, ITALY
24	CARTAGENA, SPAIN
25	VALENCIA, SPAIN
	SAN REMO, ITALY
	GENOA, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.

B. Cruise reports were reviewed.

C. Navy personnel with current or previous area experience were interviewed.

D. A preliminary report was developed which included questions on various local conditions in specific harbors.

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained.

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested pre-cautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

The Port of Ibiza is located on the island of Ibiza in the Balearic Islands (Figure 2-1). Ibiza Island is approximately 80 n mi east-southeast of Valencia, Spain and 44 n mi southwest of Mallorca (the largest of the Balearic Islands).

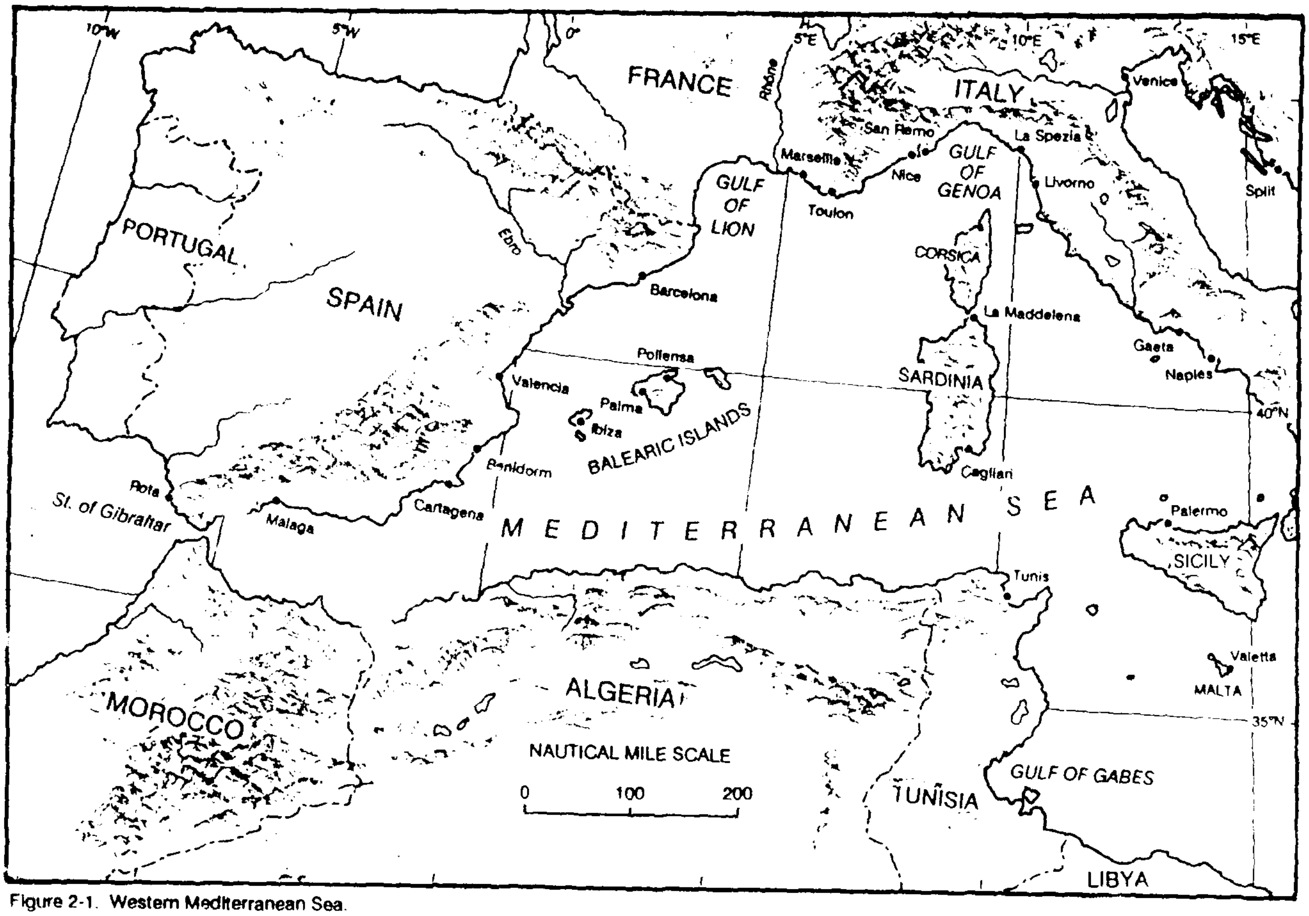

Figure 2-1. Western Mediterranean Sea.

The island of Ibiza is relatively small in size, with approximate overall dimensions of 22 n mi northeast to southwest, and 10 n mi northwest to southeast (Figure 2-2). The Port of Ibiza is situated on the southeast side of the island.

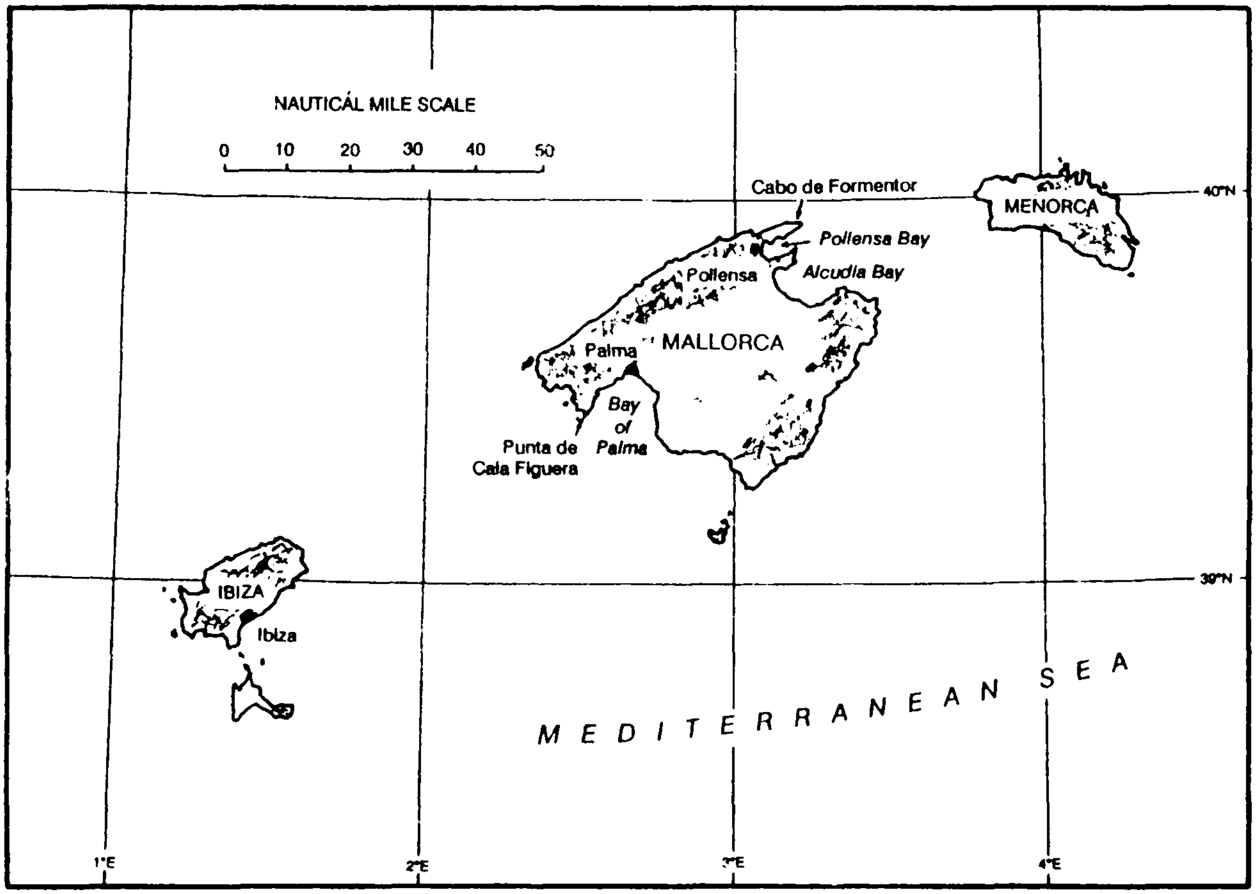

Figure 2-2. Balearic Islands.

The well-protected, small inner harbor is divided into two main basins by two piers (Figure 2-3). A fuel pier extends southwest from the northern side of the port, while Estacion Maritima pier extends northeastward from the southern side. The westernmost basin is used primarily by small boats, ferries, and fishing boats. The eastern basin is used by cruise ships, merchant vessels, tankers, and island ferries. The northeastern corner of the inner harbor is protected by a low rock wall, and is used for yachts and small boats only (FICEURLANT, 1987). The inner harbor is well protected on its south, west, and north sides by land. Except for a 250 yd (229 m) wide entrance, the eastern side is protected by two breakwaters. U.S. Navy ships do not berth in the inner harbor due to the shallow water depth, 23 ft (7 m). Instead, they use one of the anchorages described below.

One anchorage for small ships is located in the inner harbor. It can also be used by large ships for short periods during good weather, but the holding quality of the sand, vegetable matter, and mud bottom is rated fair only. Anchorages for large vessels and smaller ships on extended stays are located in the outer harbor. Three locations are identified. Ranges and bearings are in relation to Botafoch Light.

WT-1	38-54-21N	001-26-77E	bearing 097°	range 680 yd
WT-2	38-53-86N	001-26-73E	bearing 057°	range 980 yd
WT-3	38-53-63N	001-26-36E	bearing 050°	range 1,740 yd

Anchorage WT-3 has the largest swing circle and best protection for a 30-35 ft (9-11 m) draft ship. Holding is rated good in a water depth of 10 fm (18 m) (FICEURLANT, 1987).

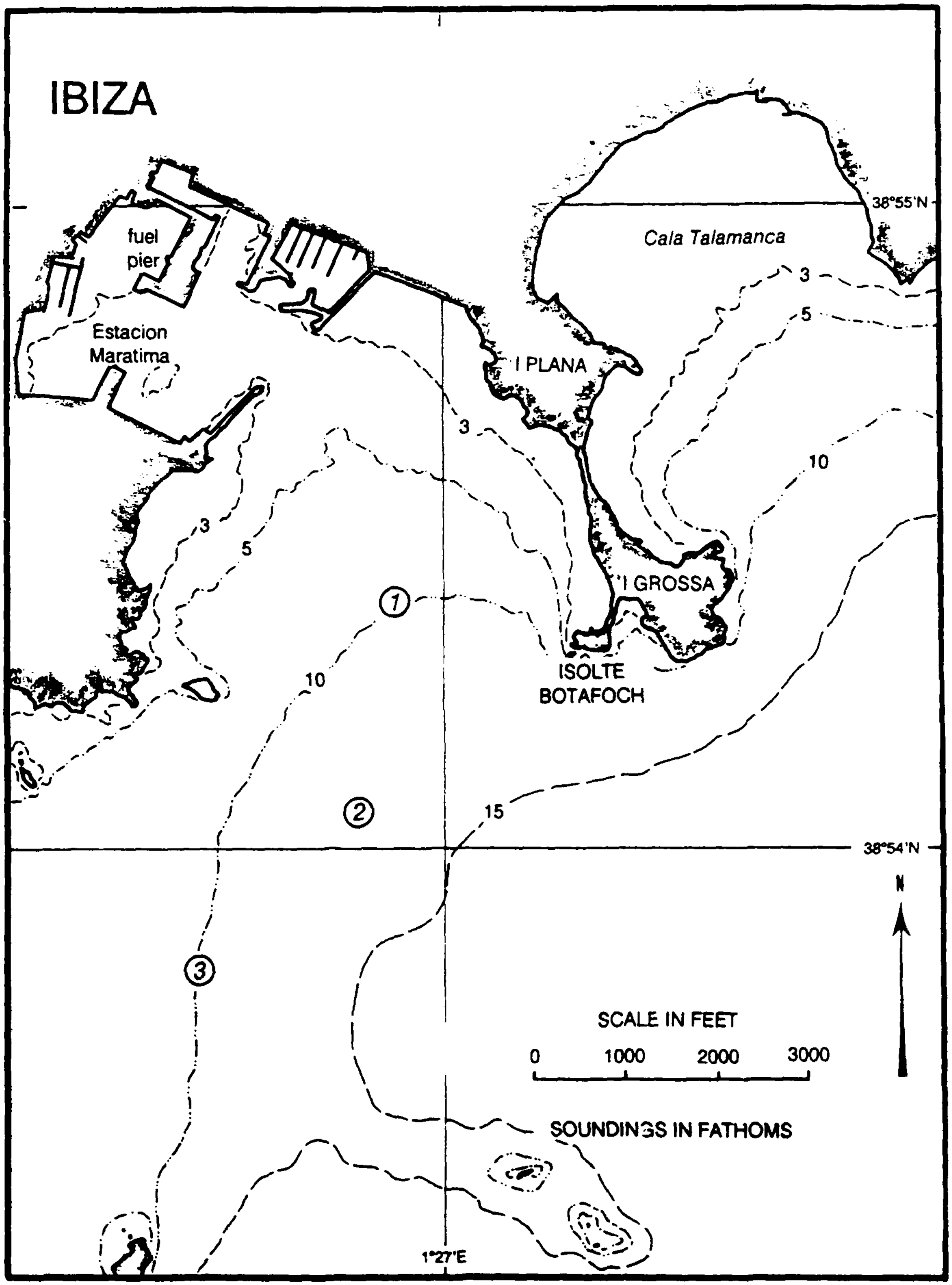

Figure 2-3. Port of Ibiza.

There are no currents which affect the harbor or anchorage. There is no astronomical tide at Ibiza, but the water level varies with wind direction by as much as 16 inches (40 cm). Southerly winds raise the water level and northerly winds lower it. Rare occurrences of rapid water level changes due to changes in wind direction have been observed. Only twice in a 33 year period has the water level in the harbor varied by 3 ft (about 1 m); damage to fenders and mooring lines resulted.

Specific hazardous environmental conditions, vessel situations, and suggested precautionary/evasive action scenarios are summarized in Table 2-1.

Table 2-1. Summary of hazardous environmen

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	S

1. <u>Mistral winds/waves</u> - Reach Port from NE.
* Wind speed is usually 15-20 kt, but may reach 35-40 kt.
* Swell height only 3 ft (1 m) due to refraction around E side of island.
	<u>Advance warning</u>
	* Mistral winds may develop when any of the following occurs:
	  * Formation of a low pressure center in Gulf of Genoa.
	  * Surface front or trough passes Perpignan (07747) or 500 mb trough passes Bordeaux (07510).
	  * When one of the following surface pressure differences is achieved:
	    * Perpignan - Marignane (Marseille), 3 mb, or
	    * Marignane - Nice, 3 mb, or
	    * Perignan - Nice, 6 mb.
	* Local indicators:
	  * Dolphin-shaped cirrus on the N horizon which are red at sunset is an indication of a Mistral beginning in 8-12 hr.
	  * A Mistral will begin in 24 hr if visibility becomes extremely good, with many stars visible at night, after the passage of a rainstorm from the Iberian Peninsula.
	
	<u>Intensity</u>
	* Strongest winds do not occur until after 500 mb trough has passed.
	* A good indication of intensity is obtained by adding 10 kt to wind speed reported by Montpelier (07643) or Istres (07647).
	
	<u>Duration</u>
	* Commonly lasts 3-4 days, but a strong Mistral may last as long as 12 days.
	* Mistral winds will cease/weaken when cyclonic regime at the surface is replaced by anticyclonic regime.
		(1
		(2
		(3

2. <u>SW'ly winds/waves</u> - Caused by low presure systems which pass through Strait of Gibraltar and move NE along E coast of Spain.
* Wind speed may reach 25 kt.
* Wind raises a dangerous chop in inner harbor.
* Outer anchorage is protected from significant wave motion.
	<u>Advance warning</u>
	* A low pressure system which indicates it will pass through the Strait of Gibraltar and move along E coast of Spain.
	* Local indicators:
	  * If the water level in the inner harbor is rising at sunrise, SW'ly winds and light rain will occur during the day.
	  * When N'ly winds die at sunset, S'ly winds will occur the following day.
		(1
		(2
		(3
		(4

cond

onmental conditions for the Port of Ibiza.

VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
(1) Anchored - outer harbor.	(a) Anchored vessels should experience no problems under normal 15-20 kt Mistral winds. * Two anchors may be required to forestall anchor dragging if wind speed increases to 35-40 kt. * Associated waves may affect small boat operations.
(2) Arriving/departing.	(a) Inbound vessels. * Anchoring vessels should be prepared to deploy 2 anchors in a strong wind situation. * Associated waves may affect small boat operations. (b) Outbound vessels. * No significant problems during departure. * Be aware of probable increased wave height once lee of Ibiza is lost.
(3) Small boats.	(a) Waves may make boat operation to/from inner harbor and outer harbor unsafe. * Boat runs may be curtailed until sea/swell abates.
(1) Anchored - inner harbor.	(a) No effect on anchored vessels. * Small boat operation to/from boat landings may be unsafe.
(2) Anchored - outer harbor.	(a) No effect on anchored vessels. * Small boat operations to/from inner harbor may be curtailed due to wind waves at anchorage. * Small boat operation near boat landings in inner harbor may be unsafe.
(3) Arriving/departing.	(a) Inbound vessels. * Vessels should not encounter problems. * Vessels should be aware of effect of chop on small boats. (b) Outbound vessels. * Vessels should not encounter problems * Vessels should be aware of probable increased wave heights once lee of Ibiza and adjacent islands S of Ibiza is lost.
(4) Small boats.	(a) Inner harbor operations may be hazardous. * Chop makes areas near berthed ship and boat landings unsafe. * Boat operation may be curtailed until conditions abate. (b) Outer harbor may experience hazardous wind waves in strong event. * Boat runs to/from the anchorage and inner harbor may be unsafe.

Table 2-1. (

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VE SI
3. NW'ly wind - Strong occurrences are possible: Gusts to 70 kt have been recorded at airport. * Likely caused by Mistral-like Cierzo winds from Ebro Valley in NE Spain. * Wave generation is minimized due to lack of fetch.	Advance warning * Strong NW'ly winds are possible soon after onset of a strong Mistral in the Gulf of Lion. See Mistral indicators above.	(1) An (2) An (3) Ar (4) Sm

1. (Continued)

VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
1. Anchored - inner harbor.	(a) Strong event may cause anchor dragging. • Two anchors may be required to forestall anchor dragging if wind is less than 50 kt. • If wind is 50 kt or more, ships should move to outer anchorage where holding quality of bottom is better. Two anchors may still be required. • Small boat operations may be affected.
2. Anchored - outer harbor.	(a) Strong event may cause anchor dragging. • Two anchors may be required to prevent dragging. • Small boat operations to/from inner harbor may be affected.
3. Arriving/departing.	(a) Inbound vessels. • If wind is strong, units should delay arrival until wind has weakened. • Anchor dragging at inner/outer anchorages is possible. • Vessels should not attempt to anchor in the inner harbor if the wind is expected to reach/exceed 50 kt. • Small boat operation is affected. (b) Outbound vessels. • Vessels should not encounter problems. • Vessels should be aware of probable increased wave heights once lee of [illegible] is lost.
4. Small boats.	(a) Wind may raise a hazardous sea in the outer anchorage. • Boat runs to/from the inner and outer harbors may be curtailed until winds abate.

For estimating shallow water wave heights, three points have been selected (Figure 2-3):

1(WT-1) 38-54-21N 001-26-77E bearing 097° range 680 yd
2(WT-2) 38-53-86N 001-26-73E bearing 057° range 980 yd
3(WT-3) 38-53-63N 001-26-36E bearing 050° range 1,740 yd

Table 2-2 provides the height ratio and direction of shallow water waves to expect at Points 1, 2, and 3 when the deep water wave conditions are known.

The Ibiza Point 1 conditions are found by entering Table 2-2 with the forecast or known deep water wave direction and period. In the following example, the height is determined by multiplying the deep water height (6 ft) by the ratio of shallow to deep height (.7).

Example: Use of Table 2-2 for Ibiza Point 1.

Deep water wave forecast as provided by a forecast center or a reported/observed deep water wave condition:

6 feet, 10 seconds, from 120°.

The expected wave condition at Ibiza Point 1, as determined from Table 2-2:

3 feet, 10 seconds, from 150°.

NOTE: Wave periods are a conservative property and therefore remain constant when waves move from deep to shallow water, but speed, height, and steepness change.

Table 2-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 2-3 for location of the points).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

IBIZA POINT 1: WT-1 — Depth 45 ft

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
060°	085°	090°	115°	155°	150°	155°
	.3	.3	.3	.3	.4	.4
090°	095°	115°	105°	115°	135°	115°
	.8	.5	.6	.6	.6	.5
120°	135°	145°	150°	140°	125°	130°
	.5	.5	.5	.7	.9	.7
150°	145°	140°	135°	135°	115°	115°
	.8	.6	.4	.6	.7	.7

IBIZA POINT 2: WT-2 — Depth 75 ft

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
060°	085°	090°	090°	090°	095°	095°
	.3	.3	.3	.4	.5	.5
090°	095°	090°	100°	110°	110°	110°
	.8	.9	.6	.6	.6	.5
120°	120°	120°	120°	120°	110°	120°
	1.0	.8	.8	.7	.5	.6
150°	150°	150°	135°	135°	115°	115°
	.9	.8	.4	.6	.6	.6

IBIZA POINT 3: WT-3 — Depth 60 ft

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
060°	085°	090°	075°	090°	085°	090°
	.3	.3	.5	.4	.5	.5
090°	090°	090°	090°	090°	100°	115°
	1.0	.8	.7	.6	.6	.6
120°	120°	130°	105°	120°	135°	125°
	.9	.8	.7	.8	.7	.9
150°	150°	150°	135°	135°	115°	105°
	.9	.8	.4	.6	.7	.8

The local wind-generated wave conditions for the anchorage area, identified as Points 1, 2 and 3, are given in Table 2-3. The fetch lengths are specifically for points 1, 2 and 3. All heights refer to the significant wave height (average of the highest 1/3 waves). Enter the local wind speed and direction in this table to obtain the minimum duration in hours required to develop the indicated fetch limited sea height and period. The time to reach fetch limited height is based on an initial flat ocean. When starting from a pre-existing wave height, the time to fetch limited height will be shorter.

Table 2-3. Ibiza. Local wind waves for fetch limited conditions at points 1, 2 and 3 (based on JONSWAP model).

Points 1, 2 & 3.

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and Fetch Length (n mi) \ Local Wind Speed (kt)	18	24	30	36	42
SW 5 n mi	<2 ft	2/3-4 1	2-3/3-4 1	3/3-4 1-2	3-4/3-4 1
SSE 15 n mi	2-3/4 2	3-4/4 2	4/4-5 2	5/5 2	6/5 2

Example:

To the south-southeast of Point 2 there is about a 15 n mi fetch (Figure 2-2). Given a south-southeast wind at 24 kt, the sea will have reached 3 to 4 feet with a period of 4 seconds within 2 hours. Wind waves will not grow beyond this condition unless the wind speed increases or the direction changes to one over a longer fetch length. If the wind waves are superimposed on deep water swell, the combined height may change in response to changing swell conditions. Wind wave directions are assumed to be the same as the wind direction.

Climatological factors of shallow water waves, as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height), are given in Table 2-4. See Appendix A for discussion of wave spectrum and energy distribution. These data are provided by season for two ranges of heights: greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m).

Table 2-4. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m) by climatological season.

IBIZA POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	11	9	3	13
Average Duration (hr)	17	19	14	28
Period Max Energy (sec)	9	9	8	9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	0	0	0
Average Duration (hr)	31	NA	NA	NA
Period Max Energy (sec)	11	NA	NA	NA
IBIZA POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	5	4	<< 1	3
Average Duration (hr)	17	12	6	10
Period Max Energy (sec)	10	10	9	9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	<< 1	0	0	0
Average Duration (hr)	6	NA	NA	NA
Period Max Energy (sec)	12	NA	NA	NA
IBIZA POINT 3:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	11	9	3	13
Average Duration (hr)	17	18	14	27
Period Max Energy (sec)	9	9	8-9	8-9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	0	0	0
Average Duration (hr)	25	NA	NA	NA
Period Max Energy (sec)	9	NA	NA	NA

SEASONAL SUMMARY OF IBIZA HAZARDOUS WEATHER CONDITIONS

WINTER (mid-January thru March):

* Mistral winds reach anchorage as NE 15-20 kt with strong events attaining 35-40 kt (swell height only 3 ft (1 m) due to refraction).
* NW'ly winds: Cierzo winds from Ebro Valley (NE Spain). Strong occurrence possible with gusts to 70 kt recorded. (Usually occur last ten days of December; may occur during January.)
* SW'ly winds: may reach 25 kt. Caused by low pressure systems passing thru Strait of Gibraltar and moving northeast along east coast of Spain.

SPRING (April to mid-June):

* Sea breeze: average velocity - 9 kt. Starts about noon and lasts until sunset.
* Thunderstorms possible.

SUMMER (mid-June thru September):

* Sea breeze: 9 kt average velocity. Starts earlier than spring (around 0800L) and lasts til sunset.
* Thunderstorm season: mid-August thru September. Very strong thunderstorms typically occur last ten days of August.
  - 5/8 sky covered with storm clouds (common).
  - 1/5 inch (.5 cm) hail, wind gusts to 40 kt, and 5.9 inches (15 cm) of rain in a 36-hour period have been recorded.

AUTUMN (October thru mid-January):

* Thunderstorm season includes first ten days of October.
* NW'ly winds: Cierzo winds from Ebro Valley (NE Spain). Strong occurrence possible with gusts to 70 kt recorded. (Usually occur last ten days of December; may occur during January.)
* SW'ly winds: may reach 25 kt. Caused by low pressure systems passing thru Strait of Gibraltar and moving northeast along east coast of Spain.

NOTE: For more detailed information on hazardous weather conditions, see previous Summary Table in this section and Hazardous Weather Summary in Section 3.

REFERENCES

FICEURLANT, 1987: Port Directory for Iibiza (1984), Balearic Islands. Fleet Intelligence Center Europe and Atlantic, Norfolk, Virginia.

3. GENERAL INFORMATION

This section is intended for fleet meteorologists/oceanographers and staff planners. Paragraph 3.5 provides a general discussion of hazards and Table 3-4 provides a summary of vessel locations/situations, potential hazards, effect-precautionary/evasive actions, and advance indicators and other information about potential hazards by season.

3.1 Geographic Location

The Port of Ibiza is located at 38°54.8'N 001°26.7'E on the island of Ibiza in the Balearic Islands (Figure 3-1). Ibiza Island is approximately 80 n mi east-southeast of Valencia, Spain, and 44 n mi southwest of Mallorca (the largest of the Balearic Islands).

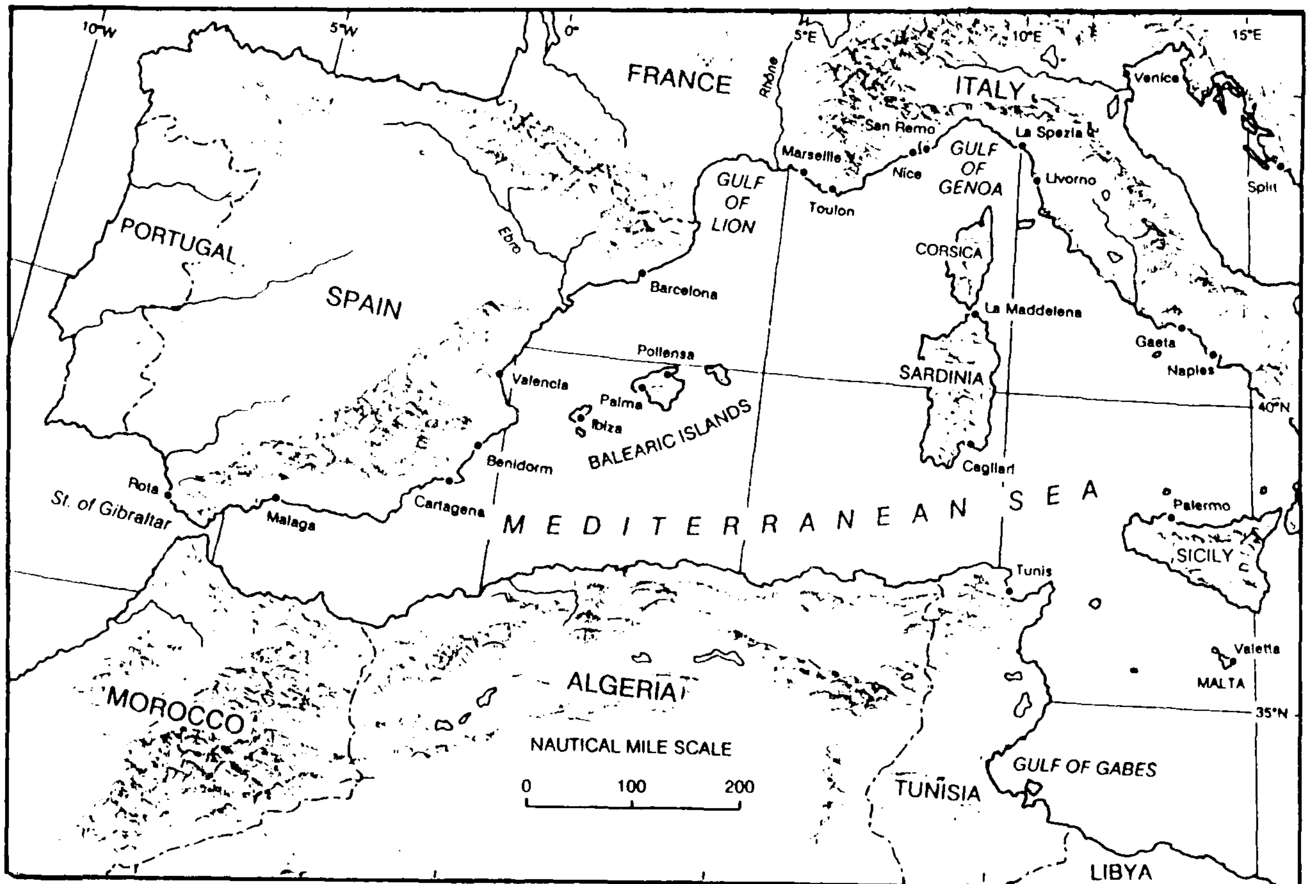

Figure 3-1. Western Mediterranean Sea.

The island of Ibiza is relatively small in size, with approximate overall dimensions of 22 n mi northeast to southwest, and 10 n mi northwest to southeast (Figure 3-2). Island topography is rugged, with maximum elevations of 1,558 ft (475 m) existing near the southwest end of the island, and 1,342 ft (409 m) near the northeast end. The Port of Ibiza is situated on the southeast side of the island.

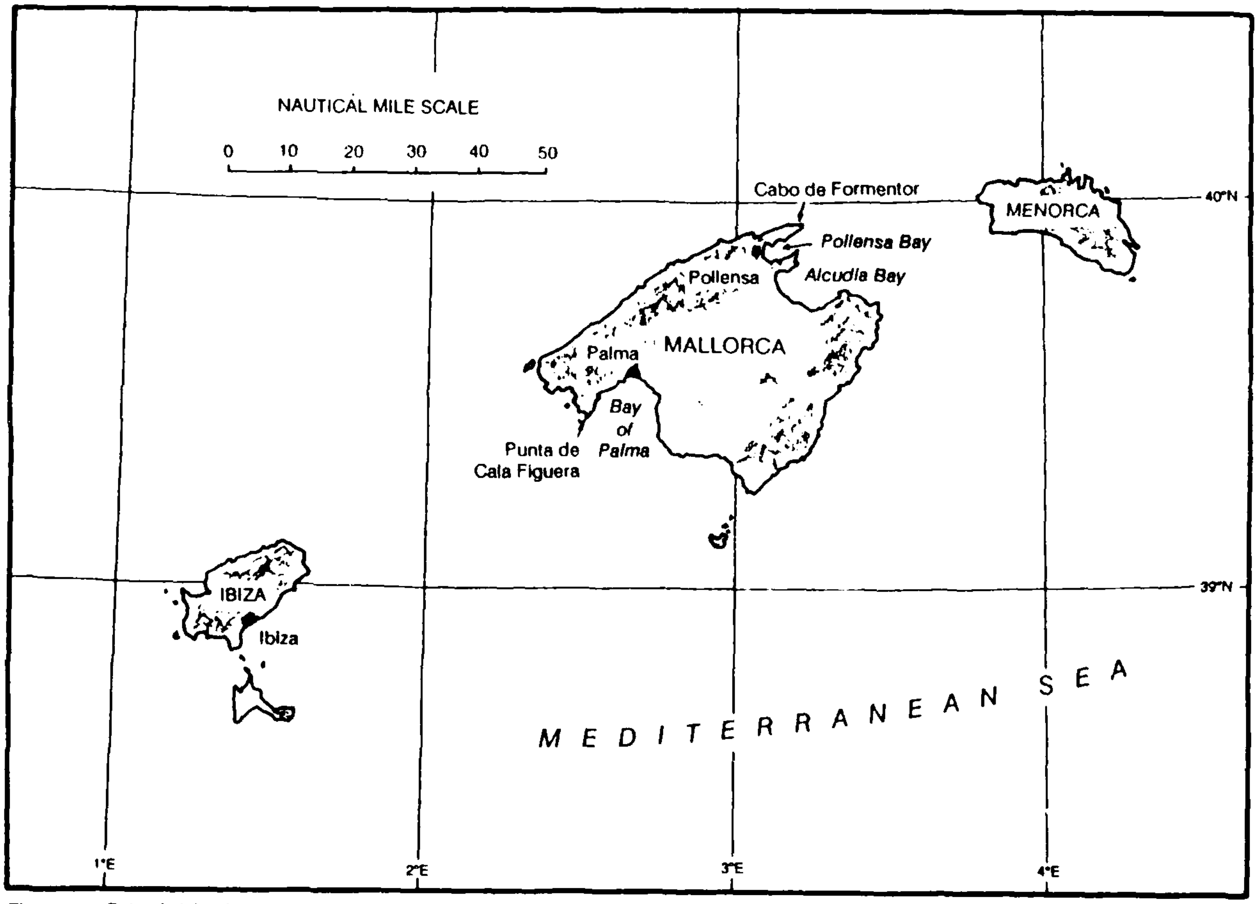

Figure 3-2. Balearic Islands.

The well-protected, small inner harbor of the port of Ibiza (Figure 3-3) is divided into two main basins by two piers. A fuel pier extends southwest from the northern side of the port, while Estacion Maritima (Maritime Station) pier extends northeastward from the southern side. The westernmost basin is used primarily by small boats, ferries, and fishing boats. The eastern basin is used by cruise ships, merchant vessels, tankers, and island ferries. The northeast corner of the inner harbor is protected by a low rock wall, and is used for yachts and small craft only (FICEURLANT, 1987). The inner harbor of the port is well protected on its south, west, and north sides by land. Except for a 250 yd (229 m) wide entrance, the eastern side is protected by two breakwaters.

One anchorage for small ships is located in the inner harbor, but vessels with a draft of more than 20 ft (6 m) are required to anchor outside the breakwater. The holding quality of the bottom of sand, vegetable matter, and mud is rated fair only. Anchorages for large vessels and smaller ships on extended stays are located in the outer harbor. Three locations are identified. Ranges and bearings are in relation to Botafoch Light.

1 (WT-1) 38-54-21N 001-26-77E bearing 097° range 680 yd
2 (WT-2) 38-53-86N 001-26-73E bearing 057° range 980 yd
3 (WT-3) 38-53-63N 001-26-36E bearing 050° range 1,740 yd

Anchorage WT-3 has the largest swing circle and best protection for a 30-35 ft (9-11 m) draft ship. Holding is rated good in a water depth of 10 fm (18 m) (FICEURLANT, 1987).

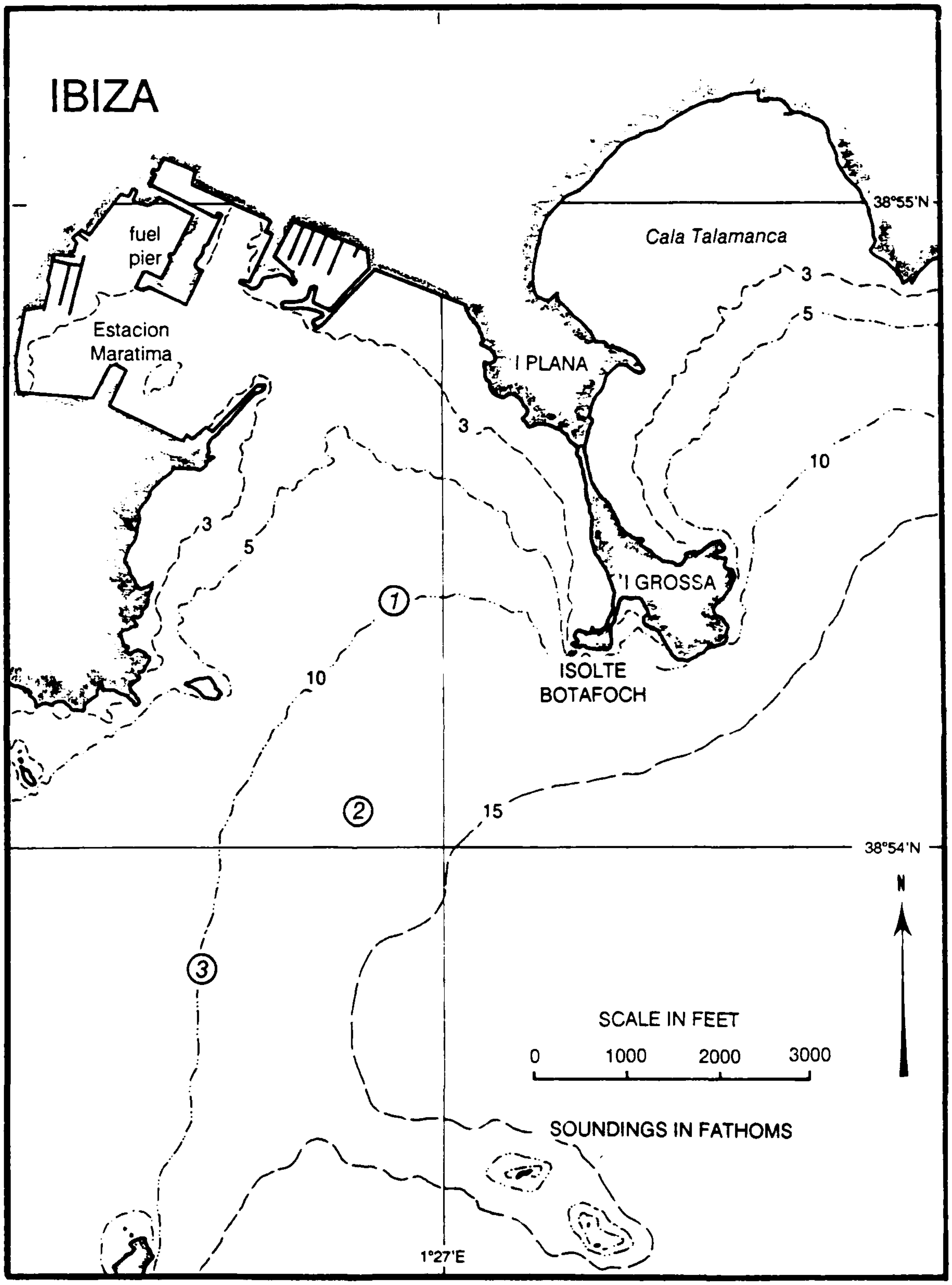

Figure 3-3. Port of Ibiza.

3.2 Qualitative Evaluation of the Port of Ibiza as a Haven

The Port of Ibiza is protected from most strong wind and resultant high wave conditions. The configuration of the coastline on which Ibiza is located effectively protects it from hazardous conditions which emanate from the south clockwise to the northeast. U.S. Navy ships do not berth in the inner harbor due to the shallow depths, 23 ft (7 m), but instead anchor in one of the designated anchorages as specified in section 3.1.

Although situated well south of the Gulf of Lion, Ibiza experiences northeasterly Mistral winds about four times each winter. Wind speeds are usually in the 15 to 20 kt range, but speeds of 30 to 40 kt are possible. Because the port is on the southeast side of the island, waves which are generated by the Mistral wind must refract clockwise around the east side of the island to reach the anchorage as an easterly swell which is usually less than 3 ft (about 1 m) high. Wind waves are not a problem in the harbor during Mistral winds because of lack of fetch. Consequently, Mistral impact is limited primarily to hazards to small boat operations.

Southwesterly winds near 25 kt occur once or twice per year. Their effect on the outer anchorage is minimized because of the configuration of the bay and the adjacent coast. The winds create very short period waves within the confines of the inner harbor, however, which raise a chop that can create hazardous conditions for small boats at boat landings.

3.3 Currents and Tides

There are no currents which affect the harbor or anchorage.

There is no astronomical tide at Ibiza, but the water level in the harbor varies with wind direction by as much as 16 inches (40 cm). Southerly winds cause a rise in water level while northerly winds lower it. Rare

occurrences of rapid water level changes due to changes in wind direction have been observed. Only twice in 33 years has the water level varied by as much as 3 ft (about 1 m). Damage to fenders and mooring lines resulted when the relatively large variation occurred.

3.4 Visibility

Surface visibility at the Port of Ibiza is normally greater than 7 n mi. About two or three times each year, during the transition from winter to spring, radiation fog will reduce visibility at the port to near 110 yd (100 m), but it is a late night/early morning phenomenon, and usually burns off by 1100L.

3.5 Hazardous Conditions

The Port of Ibiza is sheltered from most hazardous weather scenarios that affect the Balearic Island region, but has limited vulnerability to some. A seasonal summary of various known environmental hazards that may be encountered in the Port of Ibiza follows.

A. Winter (mid-January through March)

Hazardous conditions during the winter season are limited to three primary wind situations: Mistral winds which reach Ibiza as northeasterlies, Cierzo winds which infrequently reach Ibiza as strong northwesterlies, and southwesterly winds. Records from Ibiza Airport indicate that west is the predominant wind direction during January and February, with an average speed of 11-12 kt. By March, over 38 percent of the wind is from the southwest or west, with average speeds of about 9 kt.

Ibiza is located well south of the Gulf of Lion. Consequently, the Mistral winds which reach the island about four times per year during the winter season only, are not as strong as those experienced in the Gulf of Lion. Additionally, because the port is situated on the lee side of the island, Mistral wind force is commonly reduced to 15-20 kt, although it occasionally reaches 30-

40 kt. Associated waves must refract clockwise around the east side of the island to reach the nort. As a result, they are usually less than 3 ft (about 1 m) at the outer anchorage.

The Port of Ibiza infrequently experiences strong northwesterly winds. Although they usually occur during the last few days of December, they may occur during January. Isolated incidents have caused gusts to 70 kt at the Ibiza airport. They likely result from a Cierzo situation as described by Reiter (1975). A Cierzo is the Spanish term for the Mistral in the lower valleys of the Ebro River in northeastern Spain, and occurs mainly during autumn and early winter.

Southwesterly winds near 25 kt reach the port area one or two times per year. They are associated with low pressure systems which move through the Strait of Gibraltar before moving northeast along the east coast of Spain. Bay orientation and terrain minimize the effect of the wind on the anchorage, but very short period waves are created within the inner harbor. Although it is not high, the resultant chop can be hazardous to berthed ships and boat landings.

Thunderstorms occur an average of four times per year. Some are possible during the winter to spring transition period, but the strongest occurrences are experienced in late August and September. Ibiza has a drier climate than the other Balearic Islands; however, rain is not uncommon. Southwesterly winds are usually accompanied by light precipitation, but specific accumulation data are not available. Winter temperatures are moderate, though specific temperature data are not available.

B. Spring (April to mid-June)

The early part of the spring season is a more or less continuation of the winter weather regime. Exceptions to the above include the cessation of Mistral and Cierzo winds (they are winter events at Ibiza), and a gradual warming of temperatures.

Southwesterly winds prevail during the season, occurring about one-fourth of the time. Average wind speeds are generally less than 10 kt, though infrequent northwesterly winds are slightly stronger. Strong southwest wind events are possible early in the season.

A daily sea breeze becomes evident starting in May. During May, the sea breeze usually starts about noon and lasts until sunset. By June the start time advances to 0800L. The sea breeze has an easterly direction, with an average speed of about 9 kt.

Thunderstorms, which occur during the winter to spring transition period, are possible through April. Precipitation accompanying southwesterly winds continue through May, after which rain becomes less common.

C. Summer (mid-June through September)

The summer season at Ibiza is warm and pleasant. Strong winds and inclement weather are not common early in the season. Easterly winds prevail (occurring 40% of the time during July) because of the daily sea breeze. Southwest is the second most common wind direction.

The summer to autumn thunderstorm season starts in late August and continues through September. It is during this period that the strongest thunderstorms of the year occur. Very strong storms commonly occur during the last ten days of August. During these periods, as much as 5/8 of the celestial dome is often covered by cumulonimbus clouds. Hail of 1/5 inch (0.5 cm) has been recorded, as well as wind gusts to 40 kt. On one occasion, over 5.9 inches (15 cm) of rain fell during a 36-hour period.

D. Autumn (October through mid-January)

The first ten days of October are included in the summer to autumn thunderstorm season. Although the strongest storms occur in August, strong storms are still possible, along with attendant gusty winds, hail, and rain showers.

Prevailing winds shift from easterly to westerly after October. The sea breeze is still experienced

through October, but it starts later, about noon, than during summer.

Strong southwesterly winds and choppy wave conditions in the inner harbor are possible when a low pressure system passes through the Strait of Gibraltar and moves northeastward along the east coast of Spain. The winds are often accompanied by rain. Cierzo winds, which occur when Mistral-type conditions occur over the Ebro River Valley in northeastern Spain, can bring infrequent episodes of strong northwesterly winds to the Port of Ibiza.

3.6 Harbor Protection

The Port of Ibiza is protected from most hazardous situations. But as detailed below, there are differences in the protection afforded to vessels in the inner harbor and those in the anchorages outside the breakwaters.

3.6.1 Wind and Weather

The port is well protected from waves generated by various wind regimes, but is relatively exposed to the infrequent strong winds. The anchorage in the inner harbor is vulnerable, and two anchors may be required in winds to 50 kt. If 50 kt or stronger winds are expected, ships should move from the inner harbor to the outer anchorages, where holding quality of the bottom is better and bay orientation and terrain minimize the effects of the wind.

3.6.2 Waves

The inner harbor is well protected from ocean waves by its protective breakwaters. The only significant problem with waves in the inner harbor are wind waves which are generated by strong southwesterly winds. Though the fetch is short--less than 1/2 n mi--a

chop is raised in the harbor as the waves reflect off the faces of piers and sea walls. The chop is sufficient to create hazardous conditions for small boats at boat landings.

The anchorages outside the breakwaters are relatively exposed to waves from the southeast quadrant, but they are uncommon because large scale weather regimes seldom cause strong southeasterly winds at Ibiza. The anchorage does experience the 3 ft (about 1 m) swell that Mistral winds propagate to the anchorage, but no other hazardous ocean waves are identified.

Table 3-1 provides the shallow water wave conditions at the three designated points when deep water swell enters the harbor.

> Example: Use of Table 3-1.
>
> For a deep water wave condition of:
>
> 8 feet, 12 seconds, from 090°
>
> The approximate shallow water wave conditions are:
>
> Point 1: 4-5 feet, 12 seconds, from 115°
> Point 2: 4-5 feet, 12 seconds, from 110°
> Point 3: 4-5 feet, 12 seconds, from 090°

Table 3-1. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 3-3 for location of the points).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

IBIZA POINT 1: WT-1 — Depth 45 ft

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
060°	085°	090°	115°	155°	150°	155°
	.3	.3	.3	.3	.4	.4
090°	095°	115°	105°	115°	135°	115°
	.8	.5	.6	.6	.6	.5
120°	135°	145°	150°	140°	125°	130°
	.5	.5	.5	.7	.9	.7
150°	145°	140°	135°	135°	115°	115°
	.8	.6	.4	.6	.7	.7

IBIZA POINT 2: WT-2 — Depth 75 ft

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
060°	085°	090°	090°	090°	095°	095°
	.3	.3	.3	.4	.5	.5
090°	095°	090°	100°	110°	110°	110°
	.8	.9	.6	.6	.6	.5
120°	120°	120°	120°	120°	110°	120°
	1.0	.8	.8	.7	.5	.6
150°	150°	150°	135°	135°	115°	115°
	.9	.8	.4	.6	.6	.6

IBIZA POINT 3: WT-3 — Depth 60 ft

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
060°	085°	090°	075°	090°	085°	090°
	.3	.3	.5	.4	.5	.5
090°	090°	090°	090°	090°	100°	115°
	1.0	.8	.7	.6	.6	.6
120°	120°	130°	105°	120°	135°	125°
	.9	.8	.7	.8	.7	.9
150°	150°	150°	135°	135°	115°	105°
	.9	.8	.4	.6	.7	.8

Situation specific shallow water wave conditions resulting from deep water wave propagation are given in Table 3-1 while the seasonal climatology of wave conditions in the harbor resulting from the propagation of deep water waves into the harbor are given in Table 3-2. If the actual or forecast deep water wave conditions are known, the expected conditions at the three specified harbor areas can be determined from Table 3-1. The mean duration of the condition, based on the shallow water wave heights, can be obtained from Table 3-2.

Example: Use of Tables 3-1 and 3-2.

The forecast for wave conditions tomorrow (winter case) outside the harbor are:

8 feet, 14 seconds, from 060°

Expected shallow water conditions and duration:

	Point 1	Point 2	Point 3
Height	3-4 feet	4 feet	4 feet
Period	14 seconds	14 seconds	14 seconds
Direction	from 150°	from 095°	from 085°
Duration	17 hours	17 hours	17 hours

Interpretation of the information from Tables 3-2 and 3-3 provide guidance on the local wave conditions expected tomorrow at the various harbor points. The duration values are mean values for the specified height range and season. Knowledge of the current synoptic pattern and forecast/expected duration should be used when available.

Possible applications to small boat operations are selection of the mother ship's anchorage point and/or areas of small boat work. The condition duration information provides insight as to how long before a change can be expected. The local wave direction information can be of use in selecting anchorage configuration and related small boat operations, including tending activities.

Table 3-2. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m) by climatological season.

IBIZA POINT 1: WT-1	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	5	4	<< 1	3
Average Duration (hr)	17	12	6	10
Period Max Energy (sec)	10	10	9	9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	<< 1	0	0	0
Average Duration (hr)	6	NA	NA	NA
Period Max Energy (sec)	12	NA	NA	NA
IBIZA POINT 2: WT-2	**WINTER**	**SPRING**	**SUMMER**	**AUTUMN**
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	11	9	3	13
Average Duration (hr)	17	18	14	27
Period Max Energy (sec)	9	9	8-9	8-9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	0	0	0
Average Duration (hr)	25	NA	NA	NA
Period Max Energy (sec)	9	NA	NA	NA
IBIZA POINT 3: WT-3	**WINTER**	**SPRING**	**SUMMER**	**AUTUMN**
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	11	9	3	13
Average Duration (hr)	17	19	14	28
Period Max Energy (sec)	9	9	8	9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	0	0	0
Average Duration (hr)	31	NA	NA	NA
Period Max Energy (sec)	11	NA	NA	NA

Table 3-1. Cont

Local wind wave conditions are provided in Table 3-3 for Ibiza Points 1, 2 and 3. The fetch lengths are specifically for Points 1, 2 and 3. The time to reach the fetch limited height assumes an initial flat ocean. With a pre-existing wave height, the times are shorter.

Table 3-3. Ibiza. Local wind waves for fetch limited conditions at Points 1, 2 and 3 (based on JONSWAP model).

Points 1, 2 & 3.

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Direction and\ Fetch \ Length \ (n mi)	Local Wind Speed (kt) 18	24	30	36	42
SW 5 n mi	<2 ft	2/3-4 1	2-3/3-4 1	3/3-4 1-2	3-4/3-4 1
SSE 15 n mi	2-3/4 2	3-4/4 2	4/4-5 2	5/5 2	6/5 2

Example: Small boat wave forecasts for Point 2 (based) on the assumption that swell is not a limiting condition).

Forecast for Tomorrow:

Time	Wind (Forecast)	Waves (Table 3-3)
prior to 0800 LST	light and variable	< 2 ft
0800 to 1200	SSE 16-20 kt	2-3 ft
1200 to 2000	SSE 22-26 kt	building to 3-4 ft at 4 sec by 1300

Interpretation: Assuming that the limiting factor is waves greater than 3 feet, small boat operations will become marginal by 1200 and restricted by 1300.

Combined wave heights are computed by finding the square root of the sum of the squares of the wind wave and swell heights. For example, if the wind waves were 3 ft and the swell 8 ft, the combined height would be about 8.5 ft.

$$\sqrt{3^2 + 8^2} = \sqrt{9 + 64} = \sqrt{73} \approx 8.5$$

Note that the increased height is relatively small. Even if the two wave types were of equal height, the combined heights are only 1.4 times the equal height. In cases where one or the other heights are twice that of the other, the combined height will only increase over the larger of the two by 1.12 times (10 ft swell and 5 ft wind wave combined results in 11.2 ft height).

3.6.3 Wave Data Uses and Considerations

Local wind waves build up quite rapidly and also decrease rapidly when winds subside. The period and, therefore, length of wind waves is generally short relative to the period and length of waves propagated into the harbor (see Appendix A). The shorter period and length result in wind waves characterized by choppy conditions. When wind waves are superimposed on deep water waves propagated into shallow water, the waves can become quite complex and confused. Under such conditions, when more than one source of waves is influencing a location, tending or joint operations can be hazardous even if the individual wave train heights are not significantly high. Vessels of various lengths may respond with different motions to the diverse wave lengths present. The information on wave periods, provided in the previous tables, should be considered when forecasts are made for joint operations of various length vessels.

3.7 Protective/Mitigating Measures

3.7.1 Sortie/Remain in Port

Because of the shallow depths, U.S. Navy ships do not enter the inner harbor. Vessels that do moor in the inner harbor should be able remain unless winds of 50 kt or greater are forecast or occur. Additional mooring lines may be required.

3.7.2 Moving to a New Anchorage

Vessels that anchor in the inner harbor should be able to remain in winds to 50 kt. Two anchors may be required. If winds of 50 kt or greater are forecast or occur, anchored vessels should move to the outer anchorage where holding is better. Vessels in the outer anchorage should not need to move to a new anchorage under any foreseeable circumstance.

3.7.3 Scheduling

Because the Port of Ibiza is not subject to many hazardous weather events, scheduling problems are limited to avoiding the strongest daily sea breezes during the period May through October. If calm or near calm conditions are required for an evolution, it should be scheduled for early morning or late evening. Afternoon hours should be avoided. Major weather events, such as strong southwesterly or northwesterly winds, are limited to the autumn, winter, and spring seasons.

3.8 Local Indicators of Hazardous Weather Conditions

The Port of Ibiza has limited vulnerability to hazardous weather, but it is prudent to be aware of forthcoming weather events. The following guidelines have been extracted from various sources, including on-

site interviews with local authorities. They are intended to provide additional insight to the Fleet meteorologist, and enable him to recognize events that portend changes in weather conditions.

3.8.1 Mistral

Northeasterly Mistral winds reach the Ibiza anchorage about four times each winter. Speeds are usually in the 15-20 kt range, but can reach 30-40 kt. The following is an abbreviated list of Mistral guidelines that apply to the Mediterranean area in general (from Brody and Nestor, 1980). If a more complete listing is desired, refer to the accompanying NEPRF Severe Weather Guides for Marseille or Toulon, France.

1. Causes

The Mistral is the result of a combination of the following factors:

(a) The basic circulation that creates a pressure gradient from west to east along the coast of southern France. This pressure gradient is normally associated with Genoa cyclogenesis.

(b) A fall wind effect caused by cold air associated with the Mistral moving downslope as it approaches the southern coast of France and thus increasing the wind speed.

(c) A jet effect wind increase caused by the orographic configuration of the coastline. This phenomenon is observed at the entrance to major mountain gaps such as the Carcassone Gap, Rhône Valley, and Durance Valley.

(d) A wind increase over the open water resulting from the reduction in the braking effect of surface friction (as compared to the braking effect over land).

2. Onset

(a) A Mistral generally sets in when a surface front or trough passes Perpignan (07747), or the

500 mb trough passes B_rdeaux (07510). (Note: These two events are expected to occur nearly simultaneously.)

(b) Mistral onset in the Gulf of Lion occurs almost simultaneously with the formation of Genoa lows.

(c) If a 500 mb trough extends from central Europe southward over North Africa, a surface low from Algeria may propagate northward, intensify in the Gulf of Genoa, and initiate a Mistral.

(d) If a 500 mb cut-off low forms over northeast France and produces a northwesterly flow at 500 mb over the south coast, a Mistral may occur, even though 500 mb wind speeds do not reach 50 kt and the jet axis is located far to the west and south.

(e) The Mistral will start when any one of three surface pressure differences is achieved (highest pressure to the west): Perpignan - Marignane (Marseille), 3 mb; Marignane - Nice, 3 mb; or Perpignan - Nice, 6 mb. A difference usually occurs within 24 hours after a closed Genoa low appears, but it occasionally occurs earlier.

(f) Wave clouds, such as observed on high-resolution Defense Meteorological Satellite Program (DMSP) satellite imagery, are observed to form over the Massif Central of southern France approximately 6 hours before the start of a Mistral.

(g) Lus La Croix Haute (07587) will provide a two to three hour advance notice of Mistral onset. The wind speed will closely approximate the wind speed in the Gulf. (Note: Usefulness of this station is limited because it only reports every three hours.)

(h) Orange (07579) gives a good three to four hour warning of a gale force Mistral when winds at this station increase to northwesterly 25 kt. Hourly reports are available.

(i) It is possible to forecast the onset of a Mistral in the Gulf of Lion by observing changes in the normally strong afternoon sea breeze (east-southeasterly) direction at Perpignan. If the wind at this

station shifts to northerly with speeds increasing to 25-30 kt, and the temperature drops at least 3°F, a strong Mistral (40-50 kt) will be blowing in the Gulf of Lion within six hours.

3. Intensity

(a) Strongest winds associated with a Mistral do not occur until after the passage of the 500 mb trough. This usually occurs well after the surface cold frontal passage.

(b) Satellite observations indicating a strong Mistral will exhibit the following features: cloudy over France and clear over the water area south of the 1,000 ft water depth contour; clear over the Gulf of Lion except for a cloud mass, parallel to the coast, lying 75-150 n mi offshore; and/or wispy cloud streaks extending from 315° to 360° into offshore clouds.

(c) Wave clouds extending from Sardinia to Tunisia, viewed on satellite imagery, are generally associated with gale force Mistral situations.

(d) Maximum Mistral winds occur when the surface isobars are at an angle of 30° to the valleys of either the Garonne, the Rhône, or the Durance, with low pressure to the southeast.

(e) The information below can be used to estimate wind speed associated with a Mistral in the Gulf of Lion.

Pressure Difference (mb)	Perpignan* (station 07747) and Nice (station 07690)	Perpignan* and Marignane (station 07650)	Marignane** and Nice
3		30-35 kt	30-35 kt
4		40	40
5		45-50	45-50
6	30-35 kt		
8	40		
10	45-50		

* Highest pressure at Perpignan
** Highest pressure at Marignane

(f) A good indication of the intensity of a Mistral in the Gulf of Lion can be obtained by adding 10 kt to the wind speed reported by either Montpelier (07643) or Istres (07647).

(g) If the 500 mb winds reported at either Bordeaux (07510) or Brest (07110) are northwesterly at 65 kt or greater, storm force winds are indicated for the Gulf of Lion.

(h) Wind speeds over open water during a Mistral will be approximately double those measured at Perpignan or Marignane (Marseille) except in storm conditions, when the ratio will be lower.

4. Duration

(a) A strong Mistral may last for as many as twelve days without any important lulls. The most frequent length of an occurrence is about 3 1/2 days (Meteorological Office, Air Ministry, 1962).

(b) The Mistral will cease when the cyclonic regime at the surface gives way to an anticyclonic regime. Indications of this change include:

(1) The 500 mb ridge beginning to move over the Mistral area.

(2) High pressure at the surface begins to move into the western basin of the Mediterranean.

(3) There is a change that reduces the pressure difference between France and the western basin.

5. Local Indicators

The following guides were related by local authorities at the Port of Ibiza.

(a) Dolphin-shaped cirrus on the northern horizon which are red at sunset is an indicator of a Mistral beginning in eight to twelve hours.

(b) A Mistral will begin in 24 hours if visibility becomes extremely good, with many stars brightly visible at night, after the passage of a rainstorm from the Iberian Peninsula. (Note: This

guideline is similar to the one described in 3.8.1.2(a), except that the front has apparently passed Ibiza rather than Perpignan, France.)

3.8.2 Southwesterly Winds

Southwesterly winds have minimal effect on the anchorage, but a strong event can raise a hazardous chop in the inner harbor. The following guidelines were related by local authorities at the Port of Ibiza.

1. If the water level is rising in the inner harbor at sunrise, southwesterly winds and light rain will occur during the day.

2. When northerly winds die at sunset, the wind will be southerly the following day.

3.9 Summary of Problems, Actions, and Indicators

Table 3-4 is intended to provide easy to use seasonal references for meteorologists on ships using the Port of Ibiza. Table 2-1 (section 2) summarizes Table 3-4 and is intended primarily for use by ship captains.

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Table 3-4. Potential proble

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAU
1. Anchored - inner harbor. Most common in Winter Occurs in Spring & Autumn	a. SW'ly winds/waves - Caused 1-2 times per year by low pressure systems which pass through Strait of Gibraltar and move NE along E coast of Spain. Winds to 25 kt raise a sea in inner harbor which creates a chop hazardous to moored vessels and boat landings.	a. Although bottom quality is lac cause anchor dragging. Boat runs
Usually occurs during last few days of calendar year.	b. NW'ly winds - Strong occurrences are possible: 70 kt gusts have been recorded on isolated instances at airport. May be caused by Mistral-like Cierzo conditions during which strong winds flow seaward through Ebro Valley in NE Spain. May follow cold frontal passage.	b. Anchor dragging is possible. wind is expected to reach/exceed where holding is better.
2. Anchored - outer harbor. Winter only	a. Mistral winds/waves - Mistral winds reach anchorage as NE 15-20 kt, with unusually strong events attaining 35-40 kt. Attendant swell must refract around E side of island to reach Port so wave height is limited to 3 ft (about 1 m). Major impact is on small boat operations.	a. The normal 15-20 kt winds have but anchor dragging is possible i be required to avoid dragging. S vessels, but small boat runs to/f
Most common in Winter Occurs in Spring & Autumn	b. SW'ly winds/waves - Caused 1-2 times per year by low pressure systems which pass through Strait of Gibraltar and move NE along E coast of Spain. Wind velocity may reach 25 kt. Configuration of bay/terrain minimize effect at anchorage. Major effect is limited to wind wave impact on small boat operations.	b. Little effect. Wind waves may harbor.
Usually occurs during last few days of calendar year.	c. NW'ly winds - Strong occurrences are possible: 70 kt gusts have been recorded on isolated instances at airport. May be caused by Mistral-like Cierzo conditions during which strong winds flow seaward through Ebro Valley in NE Spain. May follow cold frontal passage.	c. Anchor dragging is possible, b waves may cause interruptions in

itua

l problem situations at Port of Ibiza, Ibiza.

NARY	PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
wind s om an	uality is lacking, wind strength should not be sufficient to g. Boat runs to/from anchorage may be curtailed.	c. SW'ly winds should be expected whenever a low pressure system moves through the Strait of Gibraltar and moves NE along the E coast of Spain. Local indicators of forthcoming SW winds include: (1) If the water level is rising in the inner harbor at sunrise, SW'ly winds and light rain will occur during the day. (2) When N'ly winds die at sunset, S'ly winds will occur the following day.
ment , vess	possible. Deployment of 2 anchors may be required. If each/exceed 50 kt, vessels should move to outer anchorage ter.	b. NW'ly winds should be expected whenever a strong Mistral situation is developing. Strong NW winds are most likely during the last few days of December.
gnific ds app waves nner h	t winds have no significant effect on anchored vessels, s possible if winds approach 35-40 kt. Two anchors may dragging. Swell waves should have no effect on anchored oat runs to/from inner harbor may be curtailed.	a. The following is an abbreviated listing of the many guidelines available that aid in forecasting the onset, intensity, and duration of Mistral events. Refer to section 3.8.1 of the accompanying text for a more complete listing. (1) Causes. Mistral winds result from a combination of several factors, including: (a) A W to E pressure gradient along the coast of S France. (b) Cold air moving downslope toward the S coast of France. (c) A jet effect resulting from air moving through gaps and valleys in mountains near the coast. (d) A wind increase over open water due to a lessening of surface friction. (2) Onset. (a) Mistral onset in the Gulf of Lion occurs almost simultaneously with the formation of low pressure centers in the Gulf of Genoa. (b) A Mistral generally sets in when a surface front or trough passes Perpignan (07747) or the 500 mb trough passes Bordeaux (07510). (c) The Mistral will start when one of three surface pressure differences is achieved: Perpignan - Marignane (Marseille), 3 mb; Marignane - Nice, 3 mb; or Perpignan - Nice 6 mb. A difference usually occurs within 24 hr after a closed Genoa Low appears, but it occasionally occurs sooner. (3) Intensity. (a) Strongest winds associated with a Mistral do not occur until after the passage of the 500 mb trough. (b) A good indication of the intensity of a Mistral in the Gulf of Lion can be obtained by adding 10 kt to the wind speed reported by either Montpelier (07643) or Istres (07647). (4) Duration. (a) The most frequent length of a Mistral is 3.5 days, but a strong Mistral may last for 12 days. (b) The Mistral will cease when the cyclonic regime at the surface gives way to an anticyclonic regime. (5) Local indicators. (a) Dolphin-shaped cirrus on the N horizon which are red at sunset is an indicator of a Mistral beginning in 9-12 hr. (b) A Mistral will begin in 24 hr if visibility becomes extremely good, with many stars visible at night, after the passage of a rainstorm from the Iberian Peninsula.
ct sma	nd waves may impact small boat operations to/from inner	b. SW'ly winds should be expected whenever a low pressure system moves through the Strait of Gibraltar and moves NE along the E coast of Spain. Local indicators of forthcoming SW winds include: (1) If the water level is rising in the inner harbor at sunrise, SW'ly winds and light rain will occur during the day. (2) When N'ly winds die at sunset, S'ly winds will occur the following day.
anchor boat	possible, but 2 anchors on good bottom should hold. Wind ruptions in small boat operations to/from inner harbor.	c. NW'ly winds should be expected whenever a strong Mistral situation is developing. Strong NW winds are most likely during the last few days of December.

Table 3-

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAU
3. Arriving/departing. Winter only	a. Mistral winds/waves - Mistral winds reach Port (primarily at outer anchorage) as NE 15-20 kt, but an unusually strong event may attain 35-40 kt. Attendant swell must refract around E side of island to reach the Port, so wave height is limited to 3 ft (about 1 m). Small boat operations are affected. Minimal impact on inner harbor.	a. Inbound vessels should not enco dragging is possible in strong eve anchorage may be curtailed due to be aware of probable increased wav
Most common in Winter Occurs in Spring & Autumn	b. SW'ly wind/waves - Caused 1-2 times per year by low pressure systems which pass through Strait of Gibraltar and move NE along E coast of Spain. Wind velocity may reach 25 kt. Configuration of bay/terrain minimize effect at outer anchorage, but winds raise a sea in inner harbor which creates a chop hazardous to moored vessels and boat landings.	b. Inbound vessels should not enco Mooring/anchoring should be possib to/from anchored vessels may not b waves/chop. Outbound units should once lee of Ibiza and adjacent is
Usually occurs during last few days of calendar year.	c. NW'ly winds - Strong occurrences are possible: 70 kt gusts have been recorded on isolated instances at airport. May be caused by Mistral-like Cierzo conditions during which strong winds flow seaward through Ebro Valley in NE Spain. May follow cold frontal passage.	c. If wind is strong, inbound unit Strong event can cause anchor drag harbor. Two anchors may be requir 50 kt, vessels should not attempt should experience no difficulty on aware of probable increased wave h

Table 3-4. (Continued)

PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
not encounter significant problems near Ibiza Anchor strong event. Small boat operations to/from outer d due to 3 ft (about 1 m) waves. Outbound units should eased wave heights once lee of Ibiza is lost.	a. The following is an abbreviated listing of the many guidelines available that aid in forecasting the onset, intensity, and duration of Mistral events. Refer to section 3.8.1 of the accompanying text for a more complete listing. (1) <u>Causes</u>. Mistral winds result from a combination of several factors, including: (a) A W to E pressure gradient along the coast of S France. (b) Cold air moving downslope toward the S coast of France. (c) A jet effect resulting from air moving through gaps and valleys in mountains near the coast. (d) A wind increase over open water due to a lessening of surface friction. (2) <u>Onset</u>. (a) Mistral onset in the Gulf of Lion occurs almost simultaneously with the formation of low pressure centers in the Gulf of Genoa. (b) A Mistral generally sets in when a surface front or trough passes Perpignan (07747) or the 500 mb trough passes Bordeaux (07510). (c) The Mistral will start when one of three surface pressure differences is achieved: Perpignan - Marignane (Marseille), 3 mb; Marignane - Nice, 3 mb; or Perpignan - Nice 5 mb. A difference usually occurs within 24 hr after a closed Genoa Low appears, but it occasionally occurs sooner. (3) <u>Intensity</u>. (a) Strongest winds associated with a Mistral do not occur until after the passage of the 500 mb trough. (b) A good indication of the intensity of a Mistral in the Gulf of Lion can be obtained by adding 10 kt to the wind speed reported by either Montpelier (07643) or Istres (07647). (4) <u>Duration</u>. (a) The most frequent length of a Mistral is 3.5 days, but a strong Mistral may last for 12 days. (b) The Mistral will cease when the cyclonic regime at the surface gives way to an anticyclonic regime. (5) <u>Local indicators</u>. (a) Dolphin-shaped cirrus on the N horizon which are red at sunset is an indicator of a Mistral beginning in 8-12 hr. (b) A Mistral will begin in 24 hr if visibility becomes extremely good, with many stars visible at night, after the passage of a rainstorm from the Iberian Peninsula.
ot encounter significant problems near Ibiza. possible without difficulty. Small boat operations ay not be feasible until wind subsides due to wind should be aware of probable increased wave heights ent islands S of Ibiza is lost.	b. SW'ly winds should be expected whenever a low pressure system moves through the Strait of Gibraltar and moves NE along the E coast of Spain. Local indicators of forthcoming SW winds include: (1) If the water level is rising in the inner harbor at sunrise, SW'ly winds and light rain will occur during the day. (2) When N'ly winds die at sunset, S'ly winds will occur the following day.
nd units should delay arrival until it weakens. or dragging, especially on inferior bottom of inner required. If wind is expected to reach/exceed tempt to anchor in the inner harbor. Outbound units ulty once the inner harbor is cleared, but should be wave heights once lee of Ibiza is lost.	c. NW'ly winds should be expected whenever a strong Mistral situation is developing. Strong NW winds are most likely during the last few days of December.

Table 3-1. Cont

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/E
4. Small boats. Winter only	a. Mistral winds/waves - Mistral winds reach the Port area as NE 15-20 kt, but unusually strong event may attain 35-40 kt. Attendant swell reaches outer anchorage with height of 3 ft (about 1 m) after refracting around E side of island.	a. Waves may cause interruption/curtailment of s inner harbor and outer anchorage.
Most common in winter Occurs in Spring & Autumn	b. SW'ly winds/waves - Caused 1-2 times per year by low pressure systems which pass through Strait of Gibraltar and move NE along E coast of Spain. Winds to 25 kt raise a sea in inner harbor which creates a hazardous chop at boat landings and moored vessels.	b. Chop created by wind waves in inner harbor may unsafe. Strong event may raise a hazardous sea runs to/from the inner harbor and anchored vesse
Usually occurs during last few days of calendar year.	c. NW'ly winds - Strong occurrences are possible: 70 kt gusts have been recorded on isolated instances at airport. May be caused by Mistral-like Cierzo conditions during which strong winds flow seaward through Ebro Valley in NE Spain. May follow cold frontal passage. Wind waves/chop which can be hazardous to small boat operations in inner and outer harbors may be raised.	c. Wind waves in outer harbor may make smal boat unsafe.

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(Continued)

RY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
nt of small boat operations to/from	a. The following is an abbreviated listing of the many guidelines available that aid in forecasting the onset, intensity, and duration of Mistral events. Refer to section 3.3.1 of the accompanying text for a more complete listing. (1) Causes. Mistral winds result from a combination of several factors, including: (a) A W to E pressure gradient along the coast of S France. (b) Cold air moving downslope toward the S coast of France. (c) A jet effect resulting from air moving through gaps and valleys in mountains near the coast. (d) A wind increase over open water due to a lessening of surface friction. (2) Onset. (a) Mistral onset in the Gulf of Lion occurs almost simultaneously with the formation of low pressure centers in the Gulf of Genoa. (b) A Mistral generally sets in when a surface front or trough passes Perpignan (07747) or the 500 mb trough passes Bordeaux (07510). (c) The Mistral will start when one of three surface pressure differences is achieved: Perpignan - Marignane (Marseille), 3 mb; Marignane - Nice, 3 mb; or Perpignan - Nice 6 mb. A difference usually occurs within 24 hr after a closed Genoa Low appears, but it occasionally occurs sooner. (3) Intensity. (a) Strongest winds associated with a Mistral do not occur until after the passage of the 500 mb trough. (b) A good indication of the intensity of a Mistral in the Gulf of Lion can be obtained by adding 10 kt to the wind speed reported by either Montpelier (07643) or Istres (07647). (4) Duration. (a) The most frequent length of a Mistral is 3.5 days, but a strong Mistral may last for 12 days. (b) The Mistral will cease when the cyclonic regime at the surface gives way to an anticyclonic regime. (5) Local indicators. (a) Dolphin-shaped cirrus on the N horizon which are red at sunset is an indicator of a Mistral beginning in 6-12 hr. (b) A Mistral will begin in 24 hr if visibility becomes extremely good, with many stars visible at night, after the passage of a rainstorm from the Iberian Peninsula.
...or may make small boat operation ...s sea in the outer anchorage, and make ...vessels unsafe.	b. SW ly winds should be expected whenever a low pressure system moves through the Strait of Gibraltar and moves NE along the E coast of Spain. Local indicators of forthcoming SW winds include: (1) If the water level is rising in the inner harbor at sunrise, SW ly winds and light rain will occur during the day. (2) When N'ly winds die at sunset, S ly winds will occur the following day.
...l boat operation to/from inner harbor	c. NW'ly winds should be expected whenever a strong Mistral situation is developing. Strong NW winds are most likely during the last few days of December.

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PORT VISIT INFORMATION

MAY 1987. NEPRF meteorologists D. Perryman and R. Miller met with the Port Captain, Chief Pilot and Spanish Meteorologist to obtain much of the information used in this port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always

present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period ($f = 1/T$) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining

frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \qquad (1.2)$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \qquad (1.3)$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \qquad (1.4)$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing

lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) / (hrs)	Sig Wave (H1/3) Period/Height (sec) / (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

<u>Format:</u> height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

<u>WIND FORECAST OR CONDITION</u>

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

<u>SEA FORECAST OR CONDITION</u>

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water

conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

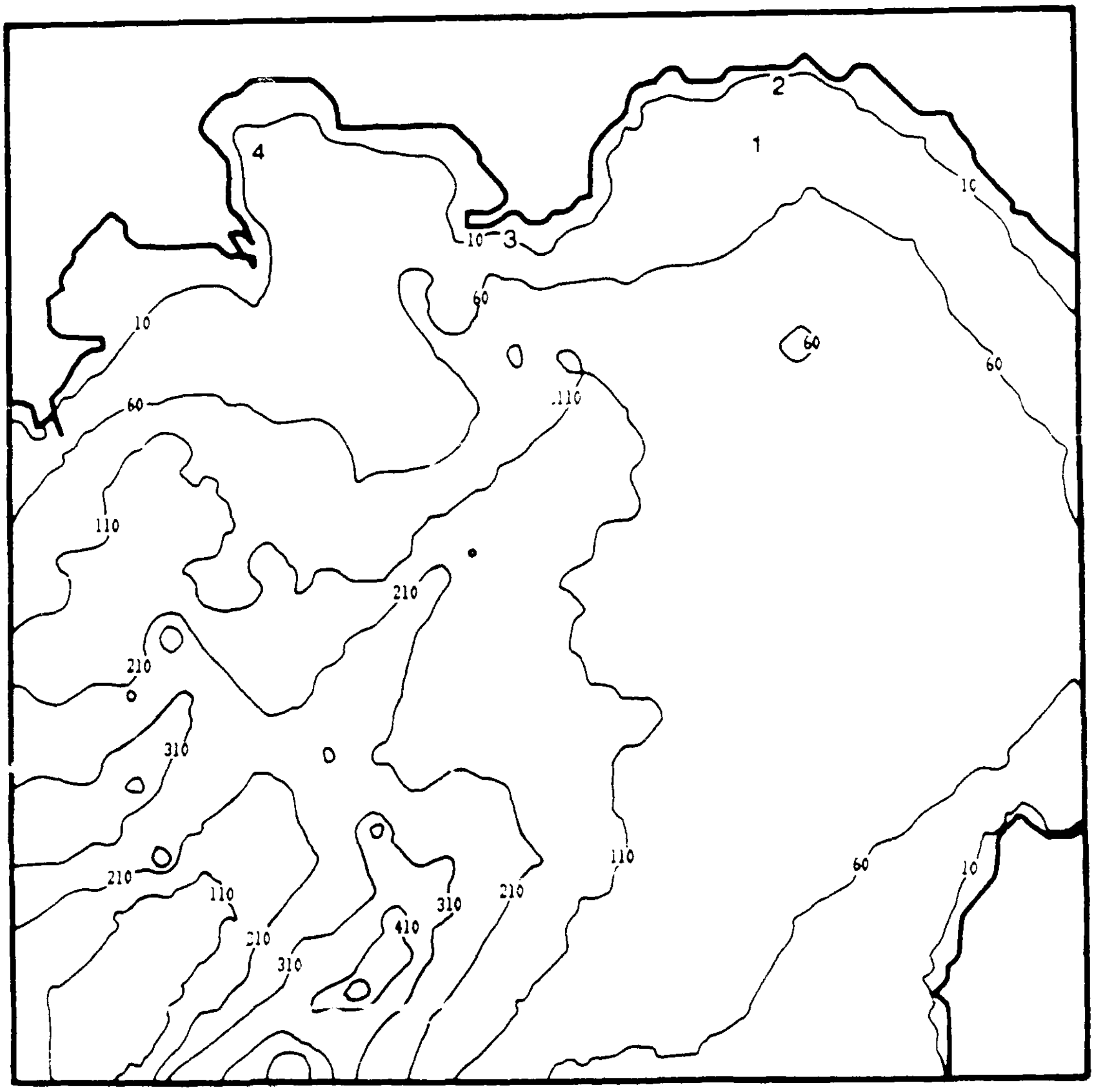

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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28L1	Amphibious Squadron LANT (2)
29A1	Guided Missile Cruiser LANT
29B1	Aircraft Carrier LANT
29D1	Destroyer LANT (DD 931/945 Class)
29E1	Destroyer LANT (DD 963 Class)
29F1	Guided Missile Destroyer LANT
29G1	Guided Missile Frigate (LANT)
29I1	Frigate LANT (FF 1098)
29J1	Frigate LANT (FF 1040/1051 Class)
29K1	Frigate LANT (FF 1052/1077 Class)
29L1	Frigate LANT (FF 1079/1097 Class)
29N1	Submarine LANT (SSN)
29[illegible]	Submarine LANT SSBN
29R1	Battleship Lant (2)
29AA1	Guided Missile Frigate LANT (FFG 7)
29BB1	Guided Missile Destroyer (DDG 993)
31A1	Amphibious Command Ship LANT (2)
31B1	Amphibious Cargo Ship LANT
31G1	Amphibious Transport Ship LANT
31H1	Amphibious Assault Ship LANT (2)
31I1	Dock Landing Ship LANT
31J1	Dock Landing Ship LANT
31M1	Tank Landing Ship LANT
32A1	Destroyer Tender LANT
32C1	Ammunition Ship LANT
32G1	Combat Store Ship LANT
32H1	Fast Combat Support Ship LANT
32N1	Oiler LANT
32Q1	Replenishment Oiler LANT
32S1	Repair Ship LANT
32X1	Salvage Ship LANT
32DD1	Submarine Tender LANT
32EE1	Submarine Rescue Ship LANT
32KK	Miscellaneous Command Ship
32QQ1	Salvage and Rescue Ship LANT
32TT	Auxiliary Aircraft Landing Training Ship

42N1	Air Anti-Submarine Squadron VS LANT
42P1	Patrol Wing and Squadron LANT
42BB1	Helicopter Anti-Submarine Squadron HS LANT
42CC1	Helicopter Anti-Submarine Squadron Light HSL LANT
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